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Maximum Power Point Tracker Using Fuzzy Logic Controller with Reduced Rules

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ABSTRACT

This paper presents a fuzzy logic controller for maximum power point tracking (MPPT) in photovoltaic system with reduced number of rules instead of conventional 25 rules to make the system lighter which will improve the tracking speed and reduce the static error, engendering a global performance improvements. in this work the proposed system use the power variation and current variation as inputs to simplify the calculation, the introduced controller is connected to a conventional grid and simulated with MATLAB/SIMULINK. The simulation results shows a promising indication to adopt the introduced controller as an a good alternative to traditional MPPT system for further practical applications.

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1. INTRODUCTION

During the last years, urgent needs for a new energy alternative in order to overcome the energy crisis and global warming issues. Those problems have significantly promoted the development of renewable energies. In this context, the photovoltaic systems represent a very competitive solution. Unfortunately, this solution is not perfect due to low energy conversion efficiency, and to overcome this problem it's necessary to provide the PV system with an MPPT controller to gather the maximum electrical power from the photovoltaic modules under different working conditions. Therefore, Many methods of MPPT were completed in previous studies, as perturb and observe (P&O) [1], fractional open-circuit voltage [2], fractional short-circuit current, incremental [2] conductance (IncCon), line approximation, ripple correlation control (RCC), PID control, fuzzy logic control (FLC)[1], genetic algorithm[3], neural network and neuro-fuzzy approaches [4]. On the other hand, intelligent systems like FLC, neural network, and neuro-fuzzy systems are able to determine their parameters and are capable of operating under the highly nonlinear system. As a result, the FLC-based MPPT algorithm attracts many research interests. Recently in literature, numerous MPPT techniques based on these techniques have been proposed [1-6]. In comparison with the P&O algorithm, they provide superior tracking performance. However, the design consideration and realization complexity for different kinds of intelligent based MPPT techniques vary widely.

Regarding the design of input/output membership functions (MFs), it is known that the input/output MFs design has a great impact on FLCs' performance in terms of tracking time. In order to deal with this issue, genetic algorithm (GA)[7], particle swarm optimization (PSO)[8] and artificial neural network (ANN)[9] are proposed in the literature to optimize the FLC MFs. In this work, we propose an MPPT based on fuzzy logic with a reduced number of rules instead of the traditional high number of rules. The goal of this reduction is to make the whole system lighter and more reactive in order to improve global performance

especially tracking time and to offer a low cost, high efficiency FLC-based MPPT algorithm, with power variation (ΔPpv) and output current variation (ΔIpv) as the inputs of the proposed FLC. The design of the FLC scheme and rule table with results will be introduced later in this paper.

2. MAXIMUM PERFORMANCE POINT TRACKER OPERATION PRINCIPLE

The connected load characteristics have an important influence on the photovoltaic operating behavior as shown in Figure 1, [10, 11]. Indeed, for a load, with an internal resistance Ri, the optimal adaptation occurs only at a particular operating point, referred to as the maximum power point (MPP) and noted in our case P max, as shown in Figure 2. Thus, when a direct connection is made between the source and the load, the output of the PV module is rarely maximum and the operating point is not optimal. To remedy this problem, it is necessary to add an MPPT controller with a DC-DC converter, between the source and the load, as shown in Figure 3 [12]. the characteristics of a PV system vary with temperature and irradiance, as shown in Figure 4, and 5 [13,14]. Therefore, an MPPT controller is also required to track the new modified maximum power point in its corresponding curve whenever a variation in temperature and/or irradiance occurs many MPPT control techniques have been conceived for this purpose in the last decades [15, 16]. They can be classified as:

1. Voltage feedback based methods, which compare the PV operating
2. Voltage with a reference voltage in order to generate the PWM control signal to be applied to the DC-DC converter [17].
3. Current feedback based methods that use the PV module
4. Short circuit current as a feedback in order to estimate the optimal current corresponding to the maximum

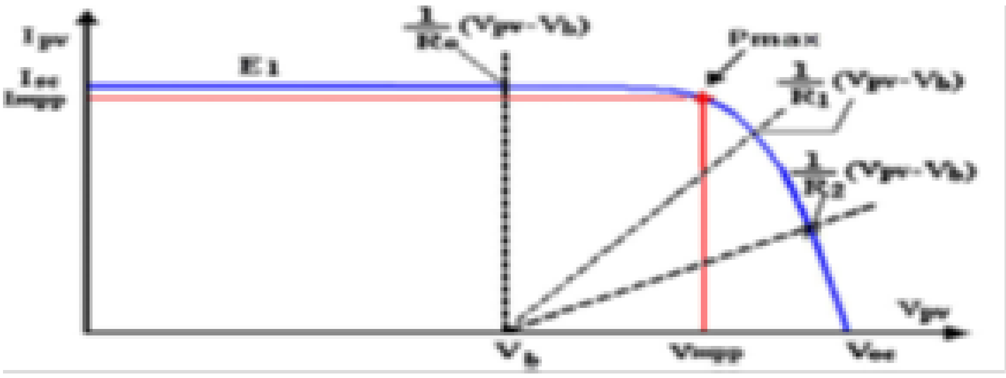

Figure 1.Current–voltage characteristic of a PV module

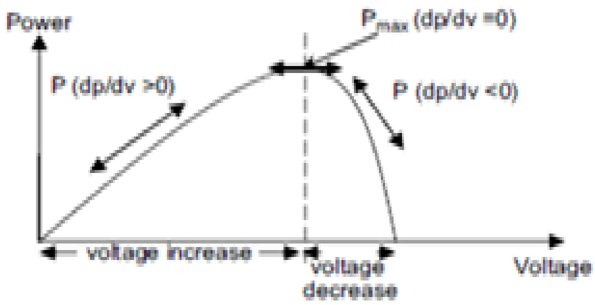

Figure 2. P-v characteristic of a PV module

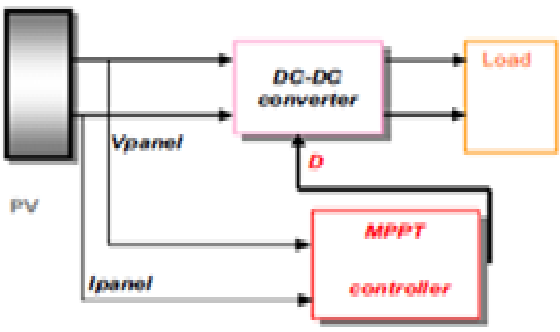

Figure 3. Photovoltaic system

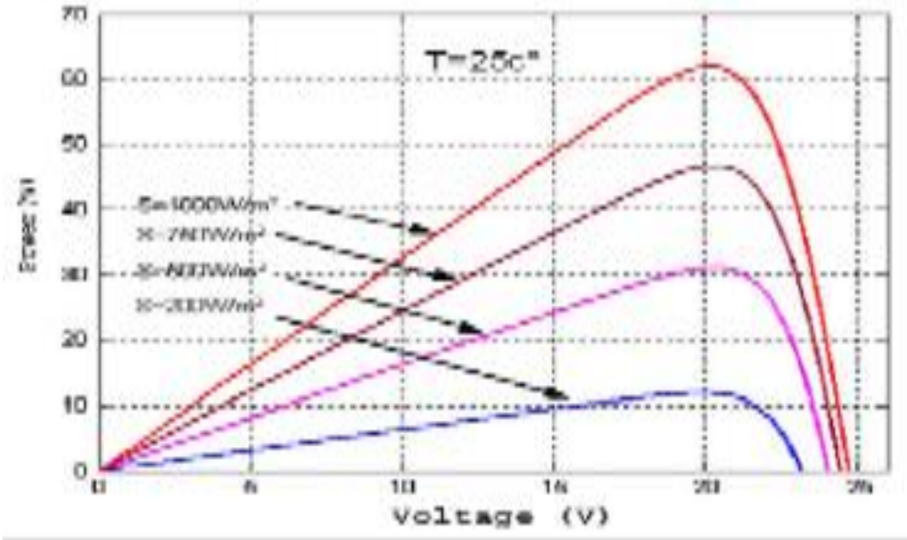

Figure. 4. Influence of the solar radiation for constant temperature

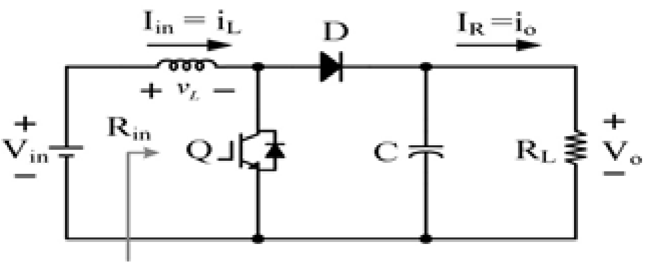

Figure 5.The boost DC-DC converter circuit

3. DC-DC CONVERTER

In order to always ensure the operation point on the maximum power point, or close to it, specific circuit, called Maximum Power Point Tracker (MPPT), is employed. Usually, the MPPT is achieved by interposing a power converter (DC-DC converter) between the PV generator and the load (battery), thus, acting on the converter duty cycle (D) it is possible to guarantee the operation point as being the MPP [18], Figure 4 shows the circuit of the buck converter, whose output voltage (Vb) is less than or equal to the input voltage Vi (PV generator voltage).

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). [20]. the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC-to-DC conversion. A boost converter is a DC-to-DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P=VI) must be conserved, the output current is lower than the source current. The dynamic model of the used boost converter as shown in Figure 4.

4. FUZZY LOGIC MPPT CONTROLLER

Fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems [12–14]. Due to their advantages and being robust and relatively simple to design since the knowledge of the exact model is not required. On the other hand, the designer needs complete knowledge of the PV system operation.

In this paper, the inputs of the proposed MPPT controller are the power variation (ΔPpv) and the current variation (ΔIpv). The MFs of the utilized input and output variables for the proposed controller are illustrated in Figure 6 shows the MFs of the input variables; both ΔPpv and ΔIpv MFs are in triangular form. Fig.7 is the MF of the output (duty cycle step size D), which is also in triangular form. In (Fig.7), DP stands for power variation, DI represents current variation and D denotes duty cycle variation. For linguistic variables, P represents positive, N represents negative, B, S and Z are defined as big, small and zero, respectively. From Figure 6, each of the input variables ΔPpv and ΔIpv is mapped into five different linguistic values. Instead usual proposed fuzzy system our model proposes a limited number of rules the fuzzy inference is carried out by using Mamdani's method, (Table 1), and the defuzzification uses the centre of gravity to compute the output of this FLC, which is the duty cycle, the control rules are indicated in Table 1. Figure 8 shows the structure of the fuzzy controller.

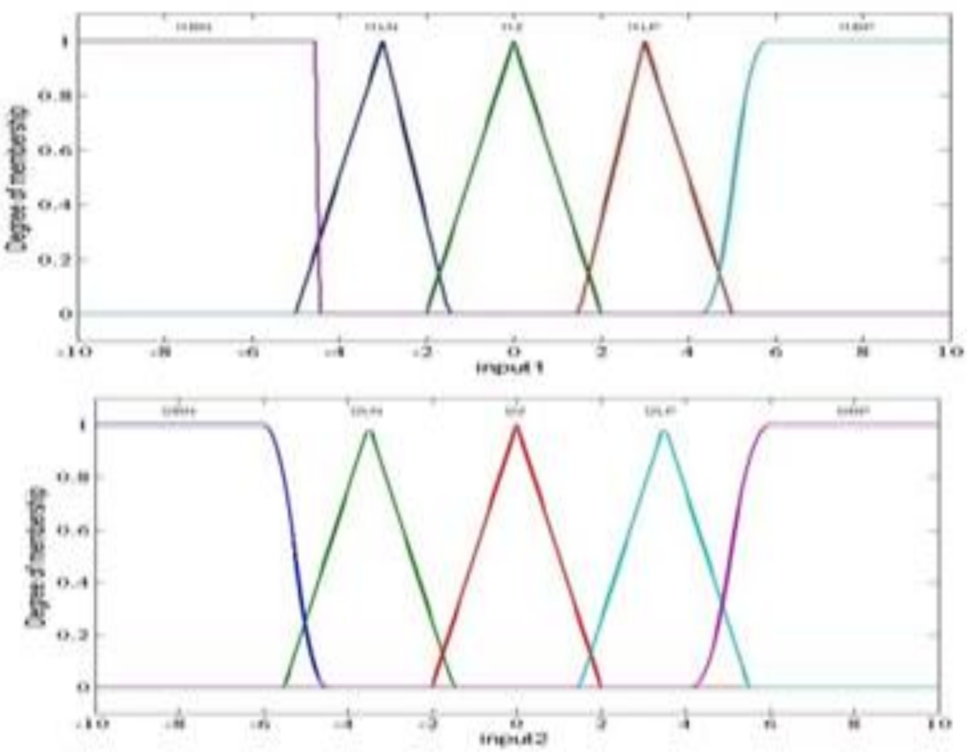

Figure 6. Membership functions for inputs (input1 DPv) (input2 DIv)

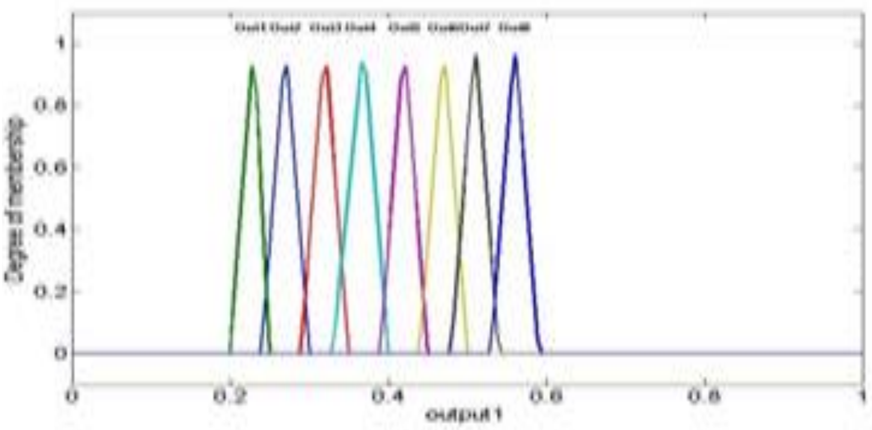

Figure 7. Membership function for output D (duty cycle)

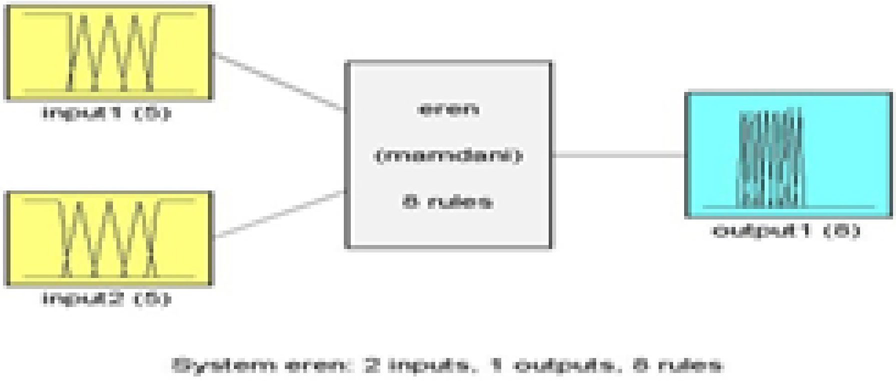

Figure 8. The structure of the fuzzy controller

5. IMPLEMENTATION AND RESULTS

5.1. IMPLEMENTATION

The proposed FLC has been implemented and tested using SIMULINK (MATLAB) to a100-kW Grid-Connected PV Array as shown in Figure 11 (Detailed Model). A step change in solar radiation applied to assess the robustness of the proposed controller. Irradiation pattern is shown in Figure 9, for the PV model we chose the SUNPOWER SPR-305-WHT as shown in Figure 10.

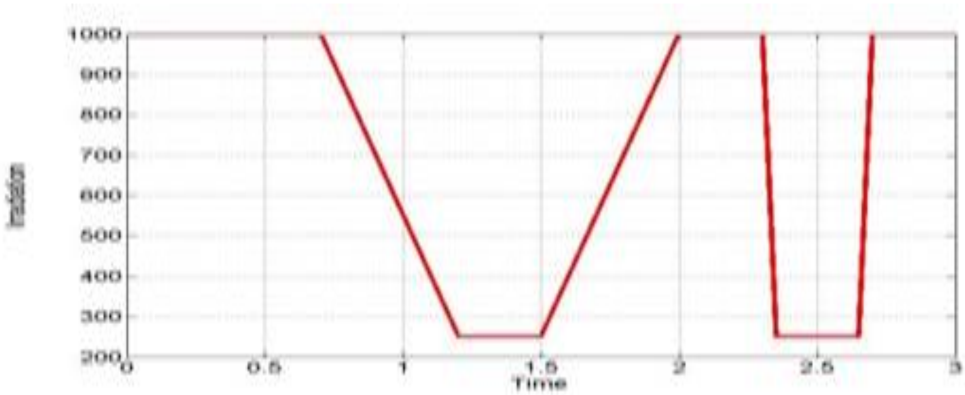

Figure 9. Irradiation pattern

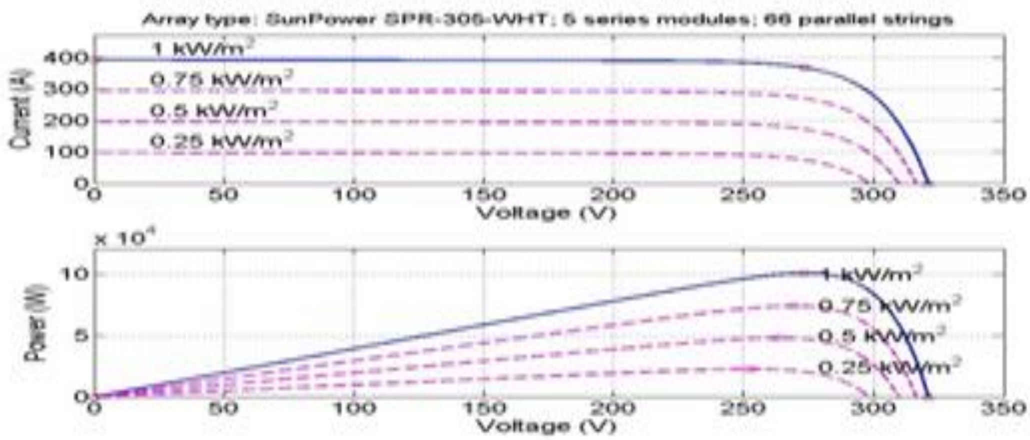

Figure 10. Array proprieties

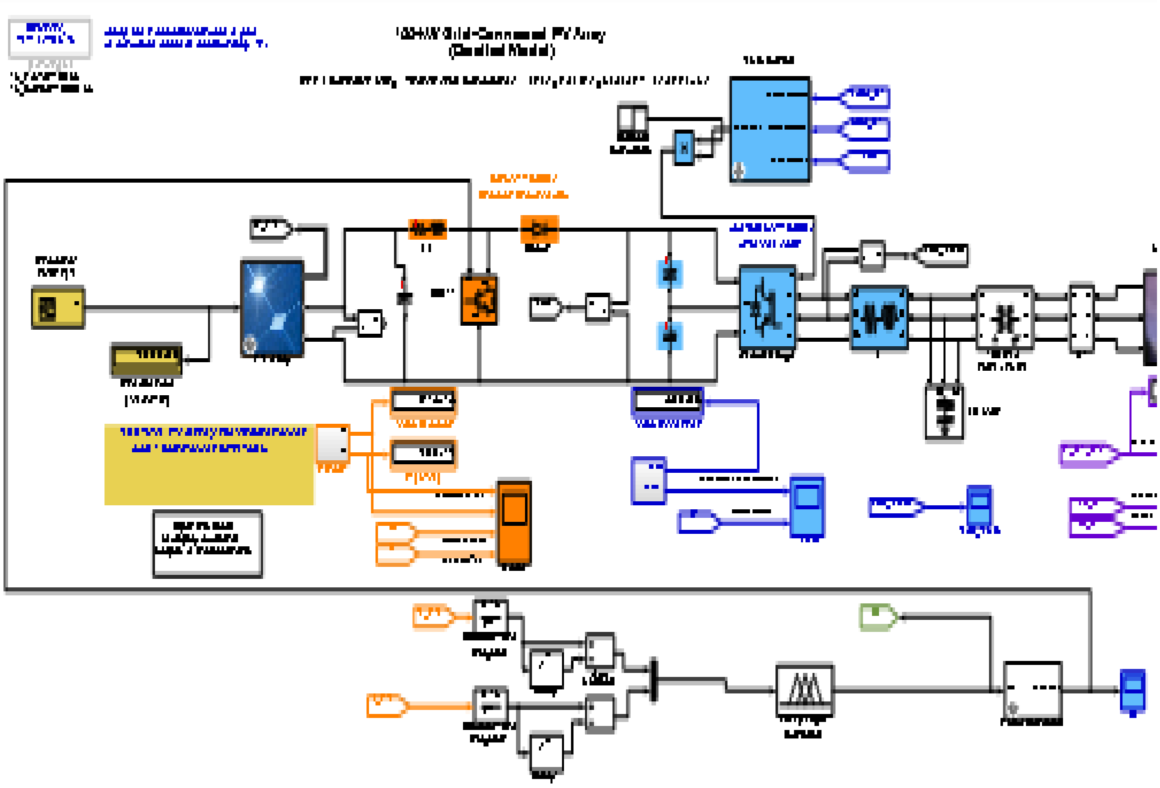

Figure 11. 100-kW grid-connected PV array

5.2. RESULTS

The simulation results of the PV generator output power as shown in Figure 12, operating voltage as shown in Figure 13, operating current as shown in Figure 14, and the duty ratio as shown in Figure 15 and grid voltage (Figure 16 using a boost converter under standard test conditions has shown that the proposed FLC controller shows better static error (1.62 kW so **1.62/100.71= 0.016%**) and less Tracking time error (less than 0.005s) comparing to conventional MPPT methods seen in previous research as shown in Table 2 [21].

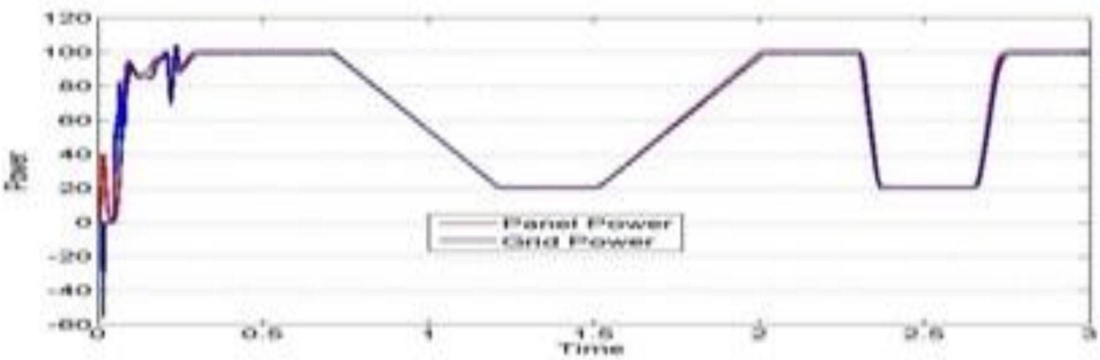

Figure 12. Generator output power

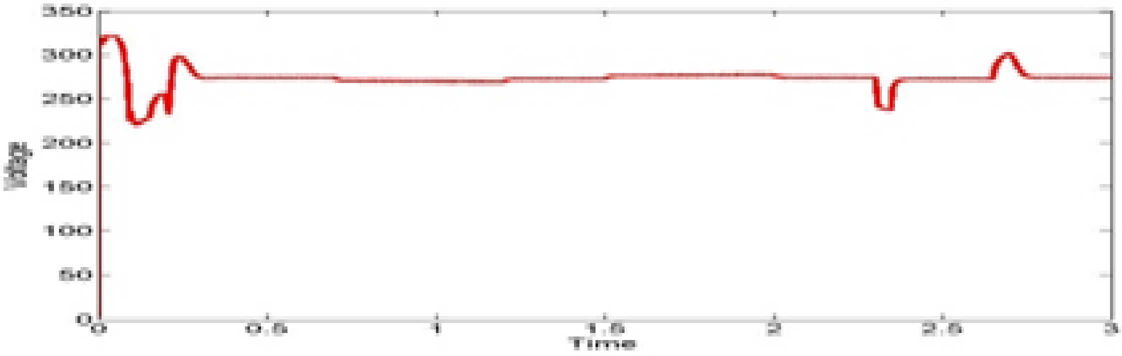

Figure 13. Operating voltage

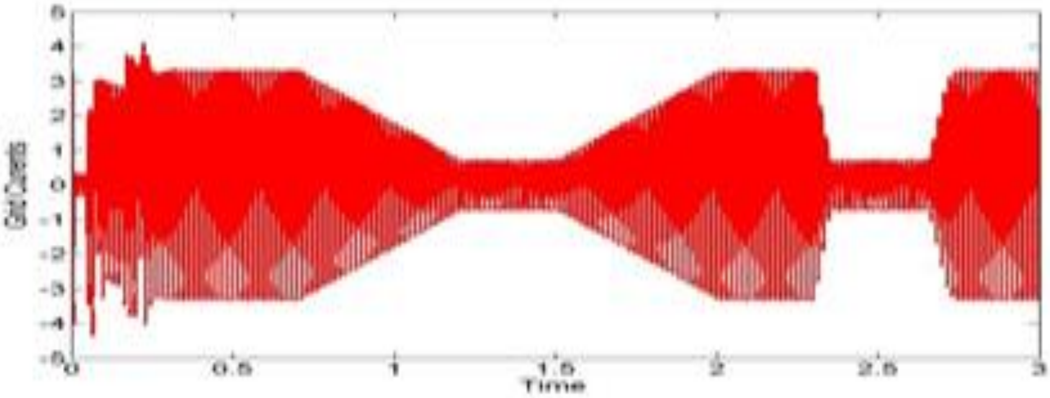

Figure 14. Grid currents

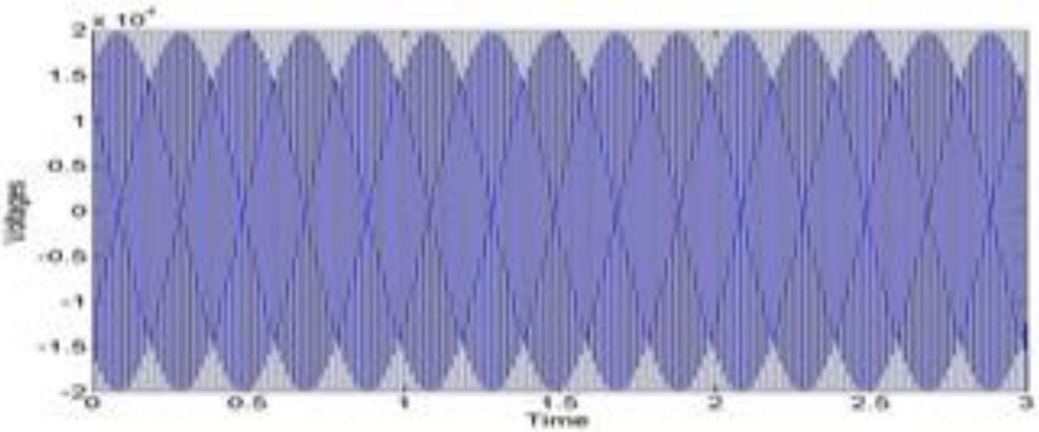

Figure 16. Grid voltage

Table 2. Comparison of Results

	FLC	P&O	FLC with reduced rules
Tracking time (Sec)	0.018s	0.015	0.005s
Static error (%)	0.25%	0.74%	0.016%

6. CONCLUSION

This paper presents a different control strategy of MPPT for the PV system using the FLC with a reduced number of rules. Simulation results show that the proposed fuzzy can track the MPP faster when compared to the conventional FLC. In conclusion, the proposed MPPT using fuzzy logic with 8 rules can improve the performance of the system and had a better response than a conventional controller in terms of the maximum power tracking time and static error.

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Farah Lotfi received the B.Eng. and Ph.D. degrees in Arabic hand written recognition from the University of BadjiMokhtar Annaba, Algeria, in 1995 and 2000, respectively. From 2000 to 2012, he was a Research Associate with the University of Cherif Messadia, Algeria. He is currently a Research with BadjiMokhtar University in GénieElectromécanique Laboratory, Annaba, Algeria. His current research interests include AI, Fuzzy System, Neural Network and Photovoltaic modeling and control, energy conversion and power electronics. He has authored and co-authored different seminar papers. Dr. Lotfi serves as a Reviewer for international journals in his research field, AI such as Journal of Computer ScienceUSA